APPENDIX C

BUILDING-WIDE FIRE: TA-55/PF-4 SOURCE TERM

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SUMMARY

A “best-estimate” source term was estimated for a postulated building-wide fire at the Plutonium Facility (PF-4) at Technical Area (TA)-55 at the Los Alamos National Laboratory. The total source term for this postulated accident is 123 grams (g) of ^{239}Pu dose equivalent. The source term comprises 56 g of ^{239}Pu dose equivalent from ^{238}Pu sources and 67 g of ^{239}Pu dose equivalent from weapons-grade plutonium sources.

1. INTRODUCTION

This appendix summarizes the analysis that was performed to determine the amount of nuclear material that might be released to the atmosphere as a result of a building-wide fire at the Los Alamos National Laboratory’s Plutonium Facility (PF-4) at TA-55. The release is termed the “airborne (radiological) building source term.”

The phenomenology of the building-wide fire was examined using deterministic analyses of fire propagation (between laboratories, between gloveboxes, and between laboratories and gloveboxes) that were undertaken as part of a Probabilistic Risk Assessment (PRA) (see Appendix B). A fire that engulfs the whole building is expected to fail all gloveboxes (the gloves burn). Therefore, radiological material in gloveboxes, as well as such material in containers on floors or shelves of laboratories or storage areas, will be exposed to fire. The analysis assumed failure of the high-efficiency particulate air (HEPA) filters in the ventilation system. Therefore, material made airborne by the fire in either the gloveboxes or the laboratories will be released to the atmosphere unhindered. However, because even the radiological material in gloveboxes is usually in containers, the fire must breach the containers before the material can become airborne. If the fire is preceded by a seismic event of a sufficient magnitude to topple gloveboxes, a mechanical dispersal of container contents may take place before their exposure to the fire. Without that mechanical breach, the containers will mitigate releases. The effects of containers on mitigating release were examined as a part of this analysis.

The following sections discuss the approach taken and the assumptions made in deriving the airborne building source term and give its magnitude.

2. APPROACH

The basic approach for determining a source term follows the methodology outlined in *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (US Department of Energy handbook DOE-HDBK-3010-94, December 1994). The handbook provides a five factor formula for determining the source term for a postulated accident at a DOE nonreactor nuclear facility. The formula is as follows:

$$BST = MAR \times DR \times ARF \times RF \times LPF .$$

Where,

MAR	is the material at risk,
DR	is the damage ratio,
ARF	is the airborne release fraction,
RF	is the respirable fraction,
LPF	is the leakpath factor,
BST	is the respirable Building Source Term.

In this analysis the values for the five factor formula are discussed individually and the approach used to determine each value is discussed.

2.1. Material at Risk (MAR)

One issue in developing the source term is how to determine the inventory of nuclear material that might be affected by the fire that is, the Material at Risk (MAR). That inventory is constantly changing and cannot be predicted precisely. However, it was decided that the inventory could be represented approximately by an arithmetic mean over the last 12 months of the inventories reported by the Material Accountability and Safeguards System (MASS) for PF-4 on a monthly basis. The method used to calculate this average is presented in the following sections.

2.1.1 MASS Data Reduction

Inventory data were extracted from the MASS system 1998 monthly reports (one set of data for each month). The data sets consisted of spreadsheets with line entries under the following heading.

Date; Account No.; Mass Location No.; Summary Material Type; Item Description; Sum of NM.

Here the *Account No*. and *Mass Location No*. locate the nuclear material (NM) for safeguard and accountability purposes. That location may be as precise as a single glovebox or as broad as a glovebox line. For this analysis, the correspondence between accountability location and gloveboxes was not made because it was not needed (example, all gloveboxes were assumed to fail).

The *Summary Material Type* (SMT) designates the nuclear material by isotope or chemical element. If it is a chemical element, it constitutes a rollup of several subcategories containing various mixes of isotopes. For example, the category *Enriched Uranium* contains subcategories of various degrees of enrichment. The Safety Analysis Report (SAR) for TA-55 combines these into one generic category, enriched uranium (EU), and defines the isotopic mix of that category. A similar rollup category gives a generic isotopic mix for weapons-grade (WG) plutonium, also treated as such in the SAR. For other generic categories, those isotopes having the worst health effects (inhalation dose conversion factors or DCFs) were taken conservatively as representative.

The *Item Description* (IDES) gives a reasonably detailed description of the material form at the identified location. The major subdivisions are as follows.

A. Assembly
B. Non-Weapon Assembly
C. Compound
E. Reactor Element
G. Gas
K. Combustible
L. Liquid/Solution
M. Metal
N. Non-Combustible
R. Process Residue

Further subdivisions distinguish between chemical forms (such as carbide, dioxide, and so on) and physical forms, such as parts, subassemblies encapsulated, standard, source, and so on. These characterizations were used to assign airborne release fractions in a first cut. Additional information on ^{238}Pu was obtained from LANL subject matter experts to refine these assignments for this source-term-dominating isotope.

2.1.2 Plutonium-239 Dose Equivalence

PF-4 contains a large number of different radioisotopes, all of which may contribute to the radiological source term; that is, they yield their own source terms. It is useful to normalize these separate inventories to that of the isotope ^{239}Pu so that the total inventory can be expressed as a single number. This was done on a dose-equivalence basis so that when the normalized inventory of any isotope is multiplied by the appropriate conversion factor for ^{239}Pu, it gives the inhalation dose to a given receptor. This approach also allows ready comparison with other source terms that may have been developed at other DOE sites.

The MASS database provides the inventories of the various isotopes in PF-4 in convenient units. These were first converted to grams. Next, the dose [in rem cumulative effective dose equivalent (CEDE)] from an inhaled gram of each isotope was extracted from the literature. This is the dose conversion factor (DCF). The ratio of the

DCF of the isotope (or isotopic mix) of interest to that of ^{239}Pu was determined. Multiplying the gram inventory of the isotope of interest by this ratio gives the inventory of that isotope in dose-equivalent grams of ^{239}Pu.

2.2. Damage Ratio (DR)

It was assumed for this analysis that the building-wide fire is sufficiently severe to involve nuclear material in all rooms of PF-4. In addition, the fire is assumed to involve all gloveboxes by burning through the gloves and exposing the nuclear material contained in the gloveboxes to ignition temperatures. This provides for a damage ratio of one.

However, the vaults are sufficiently robust and their combustible loading is sufficiently low so that they will not be affected by either an earthquake or a building-wide fire. For material in the vaults, the damage ratio is zero.

2.3. Respirable Release Fractions (RRF = ARF x RF)

Developing the source term requires an estimate of the amount of each nuclear material in each of its physico-chemical forms that becomes airborne as a result of the fire (and earthquake). This release usually is expressed in terms of the airborne release fraction (ARF) for the material form and the stress type (fire). Moreover, because the major of nuclear materials in PF-4 are all alpha emitters, the source term of primary interest is that for respirable particles. In turn, this is taken into account with the respirable fraction (RF). A complete compendium of recommended ARFs and RFs is given in DOE-HDBK-3010-94. The ARFs and RFs used in this analysis were extracted from the DOE Handbook, which provides bounding and median (most likely) values. Median values were used for this analysis to be consistent with the stated objectives of providing a “best estimate” of the amount of material released. Other assumptions used in determining ARFs and RFs are presented below.

2.3.1 Container RRFs

The DOE handbook generally provides ARFs and RFs associated with unconfined, directly exposed material. On the other hand, almost all nuclear material in the gloveboxes of PF-4 is contained in metal screw-top or slip-top containers. Material on shelves or laboratory floors is contained in drums or similar containers. Thus, nuclear material is not directly exposed in general, and the ARFs and RFs do not apply unless one assumes that the accident breaches the containers and spills all of their contents. If containers remain essentially intact, it was assumed conservatively that any release from the containers is less by an order of magnitude than that from exposed material. Some materials are encapsulated or in strong, sealed units that are tested against accident conditions. These materials are assumed not to be released at all by either a random, building-wide fire or a fire preceded by an earthquake.

2.3.2 RRFs for Non-Standard Material Forms

Where available, respirable release fractions were taken directly from the DOE Handbook. When applicable values were not available, extrapolations and interpolations were performed. As mentioned above, an extreme set of RRFs reflecting a complete breach and emptying of containers was developed. This set was applied in a first pass at developing the source term. Importantly, because the MASS database does not distinguish the dispersability of various physical forms of different chemical compounds, worst-case assumptions were made in assigning these release fractions to the inventory. In particular, all oxides were treated as fine powders even though it is known that some are in the form of granules and pellets that are effectively not dispersable as respirable aerosol.

2.3.3 Modifications to RRF

The first pass at developing the source term showed the SMT represented by ^{238}Pu to dominate by an order of magnitude. This situation motivated a more detailed look at the ^{238}Pu operations in PF-4, which led to a refinement of the RRFs for the ^{238}Pu SMT. LANL subject matter experts were consulted, and RRFs were assigned to the Mass Location Numbers identified in MASS according to the known material forms and processes at these locations. More detail on the ARFs and RFs is in a classified report by Hans Jordan on this issue written in 1999 (LA-CP-99-110).

2.4. LeakPath Factors (LPF)

A building-wide fire or a building-wide fire preceded by an earthquake is expected to provide direct leak paths to the outside.

It is expected that HEPA exhaust filters for both Zones I and II will plug with smoke and blow out if the ventilation systems are on. If the ventilation systems are off, it is likely that the heat generated by the fire will degrade the filter seals and filter medium binder enough to reduce the filtration efficiency of the HEPA filters to essentially zero.

As the respirable aerosol particles are transported out of the facility, it is likely that they will be attenuated by thermophoretic or other deposition mechanisms, but the degree of that attenuation is difficult to predict. For this analysis, such particle attenuation was assumed conservatively to be negligible. Therefore, the leak-path factor was taken as equal to one.

2.5 Building Source Term (BST)

The source term for each month of 1998 was calculated for each Summary Material Type, each Mass Location Number and each Item Description from the MASS data base by multiplying the inventory in dose-equivalent grams of ^{239}Pu (MAR) by the appropriate DR, RRF and LPF. The total source term for the month is the sum over all these individual source terms. The arithmetic mean over the last 12 months was calculated from these monthly source term values. The detailed calculations are presented in Jordan's report.

The results indicated that the major contributors to the ^{238}Pu source term are oxide powder in screw-top cans and combustible waste sealed in plastic bags contained in sealed drums. It does not appear reasonable that either of these containers would release more than 10% its contents by dropping from a shelf or glovebox in the event of an earthquake. The Department of Transportation (DOT) Type A 55-gal. drums that contain the combustible waste are certified to not release loose powder when dropped from a height of 4 ft and have been shown to remain intact for much higher falls. The contaminant on combustible material is much less dispersible by mechanical means than loose powder.

If the earthquake drops structural material from the ceiling onto the waste containers or the walls collapse onto them, it appears unlikely that more than 10% of the aggregate contents would be freely exposed to the fire. Powder containers would be shielded by gloveboxes in addition to their inherent integrity. Waste containers may deform but not fully expel material contained in sealed plastic bags and adhering to bulky material such as rags and paper towels.

Because of these considerations and consistent with the approach of the PRA, which looks at best estimates, a reasonable source term for ^{238}Pu is 56 g (^{239}Pu dose equivalent).

The source term for WG plutonium was calculated to be 113 g (^{239}Pu dose equivalent) assuming all forms of WG material are directly exposed to the fire. In fact, some of the material, such as oxide salts and powders (compounds), is in containers and unlikely to be exposed fully. It is reasonable to reduce their release by an order of magnitude as was done for ^{238}Pu. If this is done, the average source term for WG plutonium compounds is reduced from 51.2 g to 5.1 g, and the source term for all WG plutonium forms is reduced from 113 g to 67 g (^{239}Pu dose equivalent). This is the reasonable best-estimate source term for WG plutonium.

3. SUMMARY

This source-term study resulted in the following major findings.

- The radiological source term is dominated by ^{238}Pu and WG plutonium. All other isotopes in PF-4 contribute negligibly.
- The inventories of ^{238}Pu and WG Pu are remarkably constant throughout 1998 except for the month of November, for which they are down roughly by half. Therefore, the November data were discarded in estimating the likely future source term.
- The ^{238}Pu source term is 56 g (^{239}Pu dose equivalent).
- Roughly 50% of the ^{238}Pu source term is attributable to combustible waste and the ash from heat-treated waste.
- The source term attributable to WG Pu is 67 g (^{239}Pu dose equivalent)